## DECLARATION OF JAMES D. RHOADES, Ph.D.

I, JAMES D. RHOADES, Ph.D., declare and state as follows:

1. I am a consultant in the field of agricultural sciences. I have 40 years of experience assessing factors affecting crop production and soil management as related to salinity, and have published more than 200 articles, papers and books on this subject. A current curriculum vitae detailing my qualifications and experience is attached to this declaration.

2. I have been retained by the Metropolitan Water District of Southern California (Metropolitan) to assist it in evaluating the amount of Colorado River water needed to satisfy reasonable and beneficial uses within the Imperial Irrigation District (IID).

3. My opinions, findings and conclusions concerning this matter are discussed in detail in the attached reports and are summarized in the following. It is noted that the assessments provided in the attached use newer data that are more relevant to 2003 than those presented earlier (see February 21, 2003 Declaration of James D. Rhoades, submitted by Metropolitan in the IID Litigation) and, hence, the results given herein supplant the previous estimates of IID water requirements.

### Opinions, Findings And Conclusions Regarding Water-Salt Balance Methodology for Calculating IID's Beneficial and Reasonable Use Needs

4. Combined water and salt balance methodology were used, along with the water suitability irrigation model WATSUIT, to calculate the amount of water reasonably required to satisfy IID's on-farm beneficial and reasonable uses.

5. A water balance consists of all of the components (or fractions) of water needed to sustain on-farm agricultural production. A salt balance consists of all of the salt mass components associated with water use for crop production. The water fractions used in an on-farm water balance can be broken down into three general categories. The first category consists of those water fractions that are directly or indirectly consumed in crop production; they are required to sustain physical plant growth and to achieve full crop production. These fractions are those related to 1) crop transpiration (T) and 2) directly associated evaporation (E). While distinct processes, they are closely linked and are traditionally combined into a single term (value) referred to as evapotranspiration (ET), or crop consumptive use, and used to calculate this component of the irrigation water requirement. The second category consists of those water fractions used to maintain the soil salinity conditions within limits conducive to full crop production (to avoid loss in crop productivity due to excessive soil salinity). These fractions are those related to 1) removal of excess salt from the soil by vertical leaching, deep percolation and sub-surface drainage and 2) removal of excess salt from the soil by horizontal leaching, tailwater runoff and surface drainage. The third category consists of those water fractions needed to take into account real world "imperfections" or variations, such as non-uniform soil conditions, and inefficient or non-optimal farm management practices. No irrigation system is operated perfectly, so some allowance can be made in water and salt balances for the human element in on-farm irrigation practices, physical heterogeneities of soils and hydraulic constraints of field-scale irrigation. The third category of fractions are those provided to 1) compensate for non-uniformity and in-efficiency in water application, infiltration and leaching within irrigated fields and 2) for a "reasonable" allowance for tailwater runoff, if the fields are irrigated by surface gravity irrigation systems. In determining the total water duty of the entire irrigation district, one

must also include the system losses and water fractions associated with the conveyance of the waters from the source to the fields to be irrigated. These fractions are 1) system losses, including evaporation and seepage (if the canals are not lined) and 2) spillage (loss out of the end of the distribution canals), if the distribution system is comprised of open gravity canals without adequate surface storage facilities (ponds or reservoirs) to collect the overflows. In the IID, some of the diverted Colorado River water is also used for M & I and other miscellaneous uses; they must be included in the diversion requirement, as well. Some of the diverted Colorado River water is returned to the Colorado River and not delivered to IID; this credited return flow must be accounted for in the water balance assessment.

## Opinions, Findings And Conclusions Regarding Numerical Values and Procedures for Determining Water Balance Fractions

6. The team of experts assembled by MWD ("MWD Expert Team") provided me some of the numerical values for the fractions in the water balance for both on-farm deliveries and for diversion from the Colorado River, along with credited return flows. I reviewed the values they provided, and accept them as reliable values for the respective fractions.

a. For crop acreages and distributed and total crop ET, I used the data calculated, compiled, recommended and provided by Drs. R.G. Allen (2003b) and B. C. Gabrielsen (2003). Specifically, I used a volume of 1,705,289 acre-feet for the value of Colorado River crop ET, which excludes the additional volume of 28,511 acre-feet needed for duck ponds and fish farms (see Table 1c in Rhoades, 2003a or 2003c)

b. For the leaching requirement, I calculated the value of 0.06 and the corresponding volume of Colorado River water required for control of soil salinity (105,300 acre-feet, of which horizontal leaching contributed between 1,100 to 3,700 acre-feet for tailwater percentages varying from 5 to 15 percent, respectively) using the salt tolerance data published by the U S Salinity Laboratory (Maas and Grattan, (1999), the distributed volumes of consumptive use by individual crop making up the mix of crops grown in IID (Rhoades 2003a and 2003b), the average salinity level (EC = 1.09 dS/m) and composition of the Colorado River for 2000-2002 that I obtained from the U S Bureau of Reclamation Yuma Desalting Plant Laboratory, and the WATSUIT model that I developed, accounting for the contributions of both vertical (deep percolation) and horizontal leaching (tailwater), as described in Rhoades (2003a and 2003c). The latter steady-state model was demonstrated to provide essentially identical results to the most comprehensive transient model available UNSATCHEM (Rhoades, 2002). Descriptions of these models are provided in the latter reference.

c. For the non-uniformity factor, I used a value of 0.95, based on the calculations and recommendations of Drs. W. R. Walker (2003a, 2003b, 2003c) and R. G. Allen (2003a) and supported by the determination of a similar limiting value for this factor for the IID service area in my chloride mass balance assessment described elsewhere (Rhoades, 2003b and 2003c). This factor was applied as a divisor to both the volume of Colorado River water required for crop ET (1,705,289 AF) plus the volume required for vertical leaching (101,600 to

104,200 acre-feet, varying with the tailwater percentages between 15 to 5 percent, respectively) to determine the total volume of Colorado River water required to be delivered on-farm in the IID to supply all water needed for beneficial use plus a reasonable extra amount for non-uniformity compensation (resulting in about an additional 95 KAF of deep percolation) and plus extra for several scenarios of tailwater allowance; the resulting total volumes of Colorado River Water varied from 2,004.9 KAF to 2,237.6 KAF for tailwater percentages between 5 and 15 percent, respectively.

d. For "reasonable" tailwater, I and the MWD Expert Team concluded that the volume corresponding to 5% of on-farm deliveries (100.2 KAF) is a reasonable district-wide average for tailwater that can reasonably and feasibly be attained within IID with the implementation of practical and affordable management, based on the simulations and analyses of Dr. W.R. Walker (Walker, 2003a and 2003b), Dr. M. E. Grismer (2003), Dr. B. Brown and Mr. H. Payne (Payne and Brown, 2003). I concur with this potential target value. In theory, tailwater can be entirely eliminated with the implementation of required structures and irrigation systems, as it is in some other irrigation districts.

e. For duck ponds and fish farms, 28,511 acre-feet are required in addition to on-farm crop needs; for conveyance losses, M & I use, and other miscellaneous uses in the IID service area, another 455,500 acre-feet of Colorado River water are needed upstream of the farm headgates (see Scott, 2003b). Thus, 484,011 acre-feet of Colorado River water should be added to the on-farm requirements described in section c (2004.9 – 2237.6 KAF) to determine the net diversion volume at Imperial Dam, after credit for return flows, as described in Scott (2003b).

f. For credited return flows to the Colorado River, volumes varying between 79,600 and 96,800 acre-feet, depending upon the volume of net diversion, are added to net diversions to IID to obtain total diversions from the Colorado River (Scott, 2003d).

**Opinions, Findings And Conclusions Regarding Reasonableness of 5% Tailwater Value**

7. It is my conclusion, and the conclusion of the MWD Expert Team, that 5% tailwater is a reasonable target value in IID, based upon the following:

a. tailwater contributes very little to salinity control (only about 1% of the 335.6 KAF tailwater volume at a 15% fraction are beneficial in this regard). Thus, any amounts above about 3.7 KAF serve no leaching or other beneficial use function, as shown by my assessment of the beneficial volume of tailwater (see Rhoades, 2002, 2003a, 2003c);

b. reducing tailwater to 5% would not affect crop yields, as shown by the field studies carried out in the IID by the University of California, and others (see Grismer, 2003) and as demonstrated by simulations and calculations (Walker, 2003a, 2003b; Allen, 2003a; Payne and Brown, 2003);

c. 5% tailwater volumes can be achieved under IID conditions (soils, slopes, crops, etc.) through practicable and affordable management (see Payne and Brown, 2003; Walker, 2003a, 2003b);

d. other irrigation districts function well which require even lesser amounts of tailwater (see CVWD Appendix on tailwater regulation; CVWD, 2003).

**Opinions, Findings And Conclusions Regarding IID's Reasonable and Beneficial Use Needs**

8. Based upon the water and salt balance data described above, the volume of water needed to deliver on-farm to satisfy IID's beneficial and reasonable uses is determined to be 2004.9 KAF (including 5% for tailwater and another 5% for non-uniformity compensation, on a delivered water basis). This corresponds to a net diversion volume of Colorado River water of 2,489.0 KAF, assuming 484.0 KAF is needed for duck ponds, fish farms, M & I and other misc. uses, and to a total diversion volume of 2,568.6 KAF, assuming 79.6 KAF is credited as return flow water to the Colorado River for this volume of net diversion (see Scott, 2003d).

9. The total diversion volume of 2,568.6 KAF does not account for about 200 KAF in conservation measures that have already been approved for implementation, such as the All-American Canal lining project, or for other conveyance system conservation measures that have been identified and studied (Scott, 2003d). When such measures are factored in, IID's reasonable beneficial use needs drop to 2,368.6 KAF in total diversions.

10. This beneficial plus reasonable use requirement will change, if crop ET or Colorado River salinity levels change.

a. According to historical data (as analyzed and summarized by Dr. B. C. Gabrielsen, 2003), total irrigated acreage (hence total irrigation water requirements) has trended downward in IID, particularly in recent years corresponding to declines in both garden crops and field crop plantings, compared to the period 1960 to 1982 (though IID's method of reporting crop acreages is flawed, producing an over-estimate of irrigated acreages), yield trends have remained steady or trended upward for most of the primary crops grown, crop ET in the IID water service area is at a practical maximum, and reference ET (i.e., potential ET) has varied little from its 19 year average of 75.3 inches (a standard error of about + or – 0.9 inches). Based on the summary of <u>total crop ET of Colorado River</u> water of Dr. R. G. Allen (Allen, 2003b), which includes duck ponds and fish farms, the average volume for 1989-2002 is 1746.4 KAF + or – 53.2 KAF (95% probability). That for 2000-2002 is 1733.7 KAF, which is somewhat lower than the longer-term average.

b. According to Colorado River salinity data, the salinity of the Colorado River water has been relatively steady over the last five years at an EC value of about 1.1 dS/m (see Table 2 in Rhoades 2003a and 2003c).

11. If crop ET increases by 53.2 KAF (the maximum expected, based on the observed variation from 1989-2002) along with a simultaneous increase of Colorado River salinity to an EC of 1.213 dS/m (average of 1989-1996, when the salinity was relatively higher), the corresponding value of the leaching requirement would be 0.085, the volume of Colorado River water needed for on-farm delivery would be 2,128.3 KAF, the volume of needed net diversion would be 2583.8 KAF (assuming 484.0 KAF from other uses and losses) and the needed volume

of total diversion (assuming 82.7 KAF of credited returns, based on 3.2% of net diversions) would be 2,666.5 KAF, all including 5 percent tailwater and 5 percent non-uniformity compensation on a delivered water basis. Whether such changes in crop ET or salinity will occur in the future is unknown and speculative, but it provides a likely maximum upper limit for planning purposes. The prediction of ET requirements for IID for 2003 or for any future year should be based on averages, with under-prediction of ET in any one year, on average, being compensated by over-prediction in other years. Therefore, it is reasonable and correct to use the average expected ET and salinity values from recent periods (past 3 years, for example) for projection.

**Opinions, Findings And Conclusions Regarding**
**Excess Water in IID's Reinstated Current Order of 3.1 MAF Is Not Needed**

12. IID's current water order for 2003 of 3.10 MAF exceeds the total diversion volume of 2.57 MAF of Colorado River water reasonably needed (including allowances for tailwater, compensation for irrigation inefficiency and credited return-flows) by approximately 531,000 AF (3.10 - 2.57 MAF) and by approximately 731,000 AF when impending and potential system conservation measures are considered (3.10 – 2.37 MAF).

13. Most, if not all, of the above 531,000 AF amount, after deducting for return flows, consists of tailwater that flows from IID's fields. This tailwater serves no leaching (the small contribution of horizontal leaching was credited), crop ET, plant temperature control, or other beneficial use, and constitutes waste.

## Opinions, Findings And Conclusions Regarding Reasonableness of Reducing IID's Diversion By At least 300,000 AF in Calendar Year 2003

14. In my judgment, and in the judgment of the MWD Expert Team, it is reasonable and feasible to ultimately eliminate the full amount of excess tailwater (that component greater than 5%; adjusted for return flow credits) that is currently being generated in IID. However, because reducing IID's water usage (net diversion) by 531,000 AF will necessitate changes in current on-farm management practices, it is reasonable to provide some lead-time to make this adjustment. The nature and the extent of the lead time needed to reduce unnecessary tailwater is not subject to some precise mathematical calculation, but is a matter of informed judgment.

15. It is my belief, and the belief of the MWD Expert Team, that an immediate reduction in diversions that could reasonably and feasibly be required in 2003 is at least 300,000 AF; most of this reduction being tailwater.

16. This reduction of 300,000 AF in diversion for IID in 2003 is reasonable in my judgment, and the judgment of the MWD Expert Team, because:

a. reducing IID's 3.1 MAF order by at least 300,000 AF to eliminate unnecessary diversion would provide IID nearly the same level of net diversion (2.72 MAF) that IID used on average between 1976 to 1987 (2.67 MAF, when normalized for the current benefit of the IID-MWD conservation program; Scott, 2003c), when vigorous tailwater limits were being enforced (Scott, 2003b). During that same time period, IID had crop ET requirements and acreages under cultivation that exceeded those for the current time (Gabrielsen, 2003).

b. a 300,000 AF diversion reduction is additional waste that was not even occurring when the SWRCB found that IID could reasonably conserve 367,000 AF of water.

c. a 300,000 AF reduction in IID's diversion probably can be achieved simply by enforcing the 15% tailwater limits that IID has already set (Scott, 2003c).

17. In my view, and in the view of the MWD Expert Team, diversions could be reduced by more than 300,000 AF in 2003 without harm to agricultural production. However, a reduction of <u>at least</u> 300,000 AF is warranted on an immediate basis.

**Opinions, Findings And Conclusions Regarding Water Conservation Measures and Further Tailwater Reduction Goals**

18. It is my belief, and the belief of the MWD Expert Team, that further reductions in tailwater can be made after 2003 through the annual water order determinations for IID for those ensuing years.

19. In my opinion, and in the opinion of the MWD Expert Team, further reductions with the aim of achieving a district-wide tailwater volume equivalent to 5 percent or less are reasonable because:

a. tailwater reductions can be accomplished practically and affordably through the implementation of practical on-farm management practices without the need for any major infrastructure or other improvements that require any extensive lead time or financing (Payne and Brown, 2003; Walker, 2003a, 2003b);

b. the on-farm management practices described in the above references can be implemented at little or no additional economic cost to IID irrigators (Payne and Brown, 2003). Implementing these measures also will have no adverse economic effects on the greater community or the competitiveness of IID farmers (Howitt, 2003);

c. Field studies carried out in IID by the University of California have demonstrated that existing practical irrigation management practices can be implemented that are capable of reducing tailwater to less than 5 percent, without loss in yield or creation of salinity problems (Grismer, 2003). Computer simulation model studies calibrated with IID data show that such low levels of tailwater can be easily achieved with minor changes in irrigation management under IID conditions (Walker, 2003a, 2003b).

20. In order to determine the magnitude of the appropriate diversion reductions beyond the 300,000 AF reduction recommended for 2003, it is essential that the Bureau require the collection of accurate and complete data and information about tailwater losses in IID. Consequently, I believe, as does the MWD Expert Team, that the Bureau should require IID to implement by the end of 2003 a tailwater data collection program that should contain the following elements:

a. The tailwater monitoring program should be statistically representative of the geographic locations, crops, seasons and soils in the IID service area.

b. Individual tailwater measurements should be made on clearly identified fields and cover all of the irrigations on a field that season.

c. While there is no need to employ exotic or expensive flow measuring devices, tailwater measurement devices used should be calibrated to ensure a reasonable level of accuracy.

d. The tailwater monitoring program should include an irrigator advisory service that would assist the irrigator control or eliminate tailwater through specifically applicable management practices and available low-cost technologies.

e. In order to minimize contention surrounding this program and minimize or eliminate challenges to it authenticity, the annual selection of fields should be approved by an external review board comprised of experts in on-farm water management and hydography, the irrigators, IID, and the Bureau of Reclamation.

f. Chloride data needed to undertake an independent mass balance assessment of tailwater and deep percolation volumes should also be undertaken simultaneously, as recommended by Rhoades (2003b).

21. The opinions, findings and conclusions summarized above and detailed in the attached memorandum and reports are based upon my own personal and professional knowledge of and expertise in the matters that are addressed and, if called as a witness, I could and would testify competently thereto.

I declare that the foregoing is true and correct and that this declaration was executed in Riverside County, California on May 28, 2003.

James D. Rhoades

5-28-03

JAMES D. RHOADES, Ph.D.

# Curricula Vitae

**James D. Rhoades**
**5-15-03**

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**Education**

**B.S., Soil Science, University of California, 1962**
**M.S., Soil Science, University of California, 1963**
**Ph.D., Soil Science, University of California, 1966**

**Employment**

**Agricultural Salinity Consulting,** January 1999-present
**U.S. Salinity Laboratory, Agricultural Research Service, U.S.D.A.**
Research Soil Scientist, 1965-1974
Supervisory Soil Scientist, 1974-1977
Research Leader-Soil & Water Chemistry, 1977-1989
Director, 1989-1996
Senior Research Scientist, 1996-1999
Collaborator, 1999-present

**University of California**
Adjunct Associate Professor, 1976-1979
Adjunct Full Professor, 1979-present

**Selected Awards**

Phi Kappa Phi
Gamma Sigma Delta
Fellow, Soil Science Society of America
Fellow, American Society of Agronomy
Special Award for Excellence in Technology Transfer, Federal Laboratories
Applied Research Award, Soil Science Society of America
USDA Secretary's Award for Personal and Professional Excellence

**Selected Society Offices/Assignments**

Associate Editor, Soil Science Society of America Journal
Associate Editor, Plant and Soil Journal
Editorial Board, Agricultural Water Management Journal
Chairman, Chemistry Division, Soil Science Society of America
Editorial Board, American Society Civil Engineering Book on Salinity

**Technical Expertise**

Recognized internationally authority on soil and water salinity, on methods of salinity assessment, on the suitability of saline waters for irrigation, and on management strategies for utilizing saline waters for irrigation and for reducing water pollution from irrigation. Also internationally recognized for expertise in the diagnosis, reclamation and management of salt-affected soils.

**Selected International Consulting Activities**

Provided FAO (Expert Consultation on Prognosis of Salinity and Alkalinity-Rome) with recommendations on methods of water quality assessment and soil salinity appraisal. (1975)

Advised Water Research Commission of South Africa on merits of their national water quality research program and designed "core" national research program to better address their salinity pollution problems caused by irrigation. (1977)

Advised Minister of Agriculture and Water of Saudi Arabia on their soil and water salinity problems and on means to better use brackish waters for irrigation. (1978)

Advised U.S.-Canadian International Commission's Committee on Water Quality on methods of assessing water suitability for irrigation. (1978)

Advised U.S.-Canadian International Commission's Committee on Water Quality and on suitability of Poplar River for irrigation, considering its high boron concentration. (1979)

Advised FAO on program to ameliorate deteriorated, salt-affected soils in Egypt, with trips to Rome and Egypt. (1983, 1984)

Taught short course on principles and practices of salinity management for MacDonald College of McGill University and Drainage Branch of the Irrigation Division of Alberta Agriculture- Canada. (1984, 1985)

Taught short course on principles and practices of salinity diagnosis, reclamation and management for Canadian Prairie Farm Rehabilitation Administration. (1986)

Critiqued and advised Institute of Irrigation and Salinity Research, Department of Agriculture, Victoria on their research program-Australia. (1986)

Presented instruction on salinity diagnosis, reclamation and management to FAO personnel in Botswana, in Egypt and in Mexico (1987)

Advised FAO on sustainability of irrigation of chinampas in Xochimilco Mexico. (1988, 1989)

Advised Victoria State Department of Agriculture on new methods of salinity assessment-Australia. (1989)

Advised FAO on salinity and associated land degradation problems and means of rehabilitation in Iraq-Iraq. (1989)

Provided FAO and personnel of various agriculture and irrigation departments of Argentina with short course on soil salinity assessment methodology-Argentina. (1990)

Provided FAO and personnel of various agriculture and irrigation departments of Tunisia with short course on salinity diagnosis and management-Tunisia. (1990)

Advised Islamic Development Bank on development of Biosaline Institute to carry research program in Middle East to utilize saline waters for irrigation-Saudi Arabia. (1990)

Presented short course on salinity assessment and management for Gulf State nations and FAO-U.A.E. (1990)

Advised World Bank on methods of salinity assessment. (1991)

Advised World Bank on principles and management methods to reduce drainage and water pollution from irrigation. (1991)

Advised FAO (Expert Consultation on Prevention of Water Pollution by Agriculture and Related Activities) on management strategies and principles to reduce pollution of waters by irrigation-Chile. (1992)

Wrote book for FAO on Use of Saline Water for Crop Production. (1992)

Advised US-ICID and Mexican Government personnel on methods to assess and control salinity problems in irrigated regions of NW Mexico. (1993)

Presented short course on salinity management to Mexican government personnel-Mexico. (1994)

Reviewed NSF-funded salinity-related research projects in Pakistan. (1994)

Presented short course on salinity assessment and water quality management to CIHEAM-Spain. (1994)

Advised USDA-FAS and Drainage Research Institute of Egyptian Ministry of Power and Water on reuse of drainage water for irrigation. (1995, 1996, 1997)

Advised Desert Research Institute of Japan on salinity assessment technology-Japan. (1996)

Advised various Australian agencies and University of Sidney on research program for salinity assessment and control in irrigated lands-Australia. (1996)

Wrote position paper for FAO on salinity issues and needs in Middle East (1997)

Wrote book for FAO on Methods of Soil Salinity Assessment. (1998/1999)

Advised World Bank on large sodic soil reclamation project in northern India (1999)

**Selected National Consulting**

Primary salinity consultant to US Bureau Of Reclamation, 1999-present

Primary salinity consultant to Soil and Water West, Inc., 2000-present

Salinity consultant on irrigation issues to Metropolitan Water District of Southern California, 2002-present

**Selected Publications**

Author of over 200 scientific publications related to salinity assessment, diagnosis, reclamation and management, including the leading book-chapters and books describing the technology of salinity assessment, suitability of water for irrigation, use of saline waters for irrigation and protection of water quality from irrigation. The following are illustrative of these publications, with emphasis on the more recent ones:

Rhoades, J.D. 1989. Overview: Diagnosis of salinity problems and selection of control practices. ASCE Salinity Handbook. *In:* K.K. Tanji (ed.), Agri. Salinity Assessment & Management, ASCE Manuals & Reports on Eng., No. 71, ASCE, N.Y., pp. 18-41.

Rhoades, J.D. and A. Dinar. 1991. Reuse of agricultural drainage water to maximize the beneficial use of multiple water supplies for irrigation. Chap. 6. *In:* A. Dinar and D. Zilberman (eds.), "The Economics and Management of Water and Drainage in Agriculture", pp. 99-115, Kluwer Academic Publ.

Rhoades, J.D. 1992. Instrumental field methods of salinity appraisal. *In:* G.C. Topp, W.D. Reynolds and R.E. Green (eds.); Advances in Measurement of Soil Physical Properties: Bringing Theory into Practice. SSSA Special Pub. No. 30, pp. 231-248.

Rhoades, J.D., A. Kandiah and A.M. Mashali. 1992. The use of saline waters for crop production. FAO Irrigation & Drainage Paper 48, FAO, Rome, Italy. 133 p.

Rhoades, J.D. 1993. Electrical conductivity methods for measuring and mapping soil salinity. *In:* D.L. Sparks (ed.), Advances in Agronomy. Vol. 49:201-251.

Rhoades, J.D. 1996. Salinity: Electrical conductivity and total dissolved solids. *In* D. L. Sparks (ed.), Soil Sci. Soc. Am. Book Series: 5, Methods of Soil Analysis, Part 3, Chemical Methods, Soil Sci. Soc. Of Amer., Inc., Madison Wisconsin, pp 417-435.

Rhoades, J. D., S.M. Lesch, S.L. Burch, R.D. LeMert, P.J. Shouse, J.D. Oster, and T. O'Halloran. 1997. Salt distributions in soil profiles and fields and salt pick-up by run-off waters. J. Irrig. & Drainage Engineering 123:323-328.

Rhoades, J.D., N.A. Manteghi, S.M. Lesch, and D.C. Slovacek. 1997. Determining soil & water sodicity from electrode measurements. Commun. Soil Sci. & Plant Analysis 28:1737-1765.

Rhoades, J.D., S.M. Lesch, R.D. LeMert and W.J. Alves. 1997. Assessing irrigation/drainage/salinity management using spatially referenced salinity measurements. Agr. Water Mgt. 35:147-165.

Rhoades, J. D. 1997. Sustainability of irrigation: An overview of salinity problems and control strategies. Keynote Presentation/Paper, Proc. Canadian Water Resources Association, Annual Meeting, 1997.

Rhoades, J. D., S. M. Lesch and D. L. Corwin. 1999. Geospatial measurements of soil electrical conductivity to assess soil salinity and diffuse salt-loading from irrigation, pp. 197-216, *In* (D. L. Corwin, K. Logue and T. R. Ellsworth (eds.), "Assessment of Non-Point Source Pollution in Vadose Zone, Geophysical Monograph 108, American Geophysical Union, Wash., DC

Rhoades, J. D. 1999. Soil Salinity Assessment: Methods and Interpretation of Electrical Conductivity Measurements. FAO Irrigation & Drainage Paper 57, FAO, Rome, Italy. 150 p.

Rhoades, J. D. 1999. Use of Saline Drainage Waters for Irrigation. *In* R. W. Skaggs and J. van Schilfgaarde (eds.), Agronomy Monograph 38, American Society of Agronomy. Inc., Madison Wisconsin, pp 615-658.